

EXHIBIT 5



DIRECTED ENERGY, INC.

**PCO-7110
Laser Diode Driver Module**

**INSTALLATION
and
OPERATION
NOTES**



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Doc #9100-0214 Rev 4**

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Introduction

The PCO-7110 is a compact, economical OEM pulsed laser diode driver module. It is designed to provide extremely fast, high current pulses to drive laser diodes in range finder, LIDAR, atmospheric communications and other applications requiring high current, nanosecond pulses.

Six standard models are offered in the PCO-7110 product line, providing pulse currents ranging from 4A to 120A, and pulse widths from 4 nanoseconds to 65 nanoseconds, at frequencies as high as 50KHz. The PCO-7110 is designed to be an Original Equipment Manufacturer (OEM) style product in which the current pulse may be easily tailored to the diode type and application – contact DEI for more information.

Mounting pads are provided to mount the laser diode directly to the driver. The four-hole mounting pattern accepts TO-18, TO-5, TO-52, 5.6MM, and 9MM packages (EG&G Optoelectronics R, S, T and U packages), as well as other packages of similar dimensions and lead spacing, mounted perpendicular to the driver circuit board. To facilitate different packages and mounting preferences, there are two solder pads on the end of the board to accept various laser diode packages mounted on axis to the driver. Furthermore, the diode can be connected remotely from the driver using a low-impedance stripline interconnection between the mounting pads and the leads of the laser diode.

A current monitor output may be viewed with an oscilloscope, providing a straightforward means to observe the diode current waveform in real-time.

The design is inherently temporally stable with large variations in ambient temperature and equally rugged with respect to mechanical parameters.

Design Considerations

Many elements and stray components may affect the PCO-7110 performance. One of the most important, which affects the performance greatly, is stray inductance. This is a combination of the output current loop's circuit elements and the physical inductance of that loop. The magnitude of this inductance has a great effect on the pulse width and the peak output current. The PCO-7110 design minimizes the stray inductance of the circuit components to approximately 2nH. However, the laser diode that it will drive and the means by which the diode is connected to the PCO-7110 also contribute to the stray inductance. This additional inductance, which is added to the system and will affect the output, is something that the user can minimize by appropriate diode package choice and interconnections between the diode and driver.

Table 1 lists several laser diode package types and their Equivalent Series Inductance (ESL). Although many of the laser diode packages have the appearance of a good low inductance design, they are not. For example, the 8-32 STUD (line # 2) from all outward appearances is a low inductance package, however it has one of the largest ESL's of the devices listed. As shown in Table 1, this leaves the laser diode as the largest contributor of the total inductance.


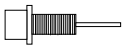
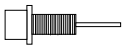




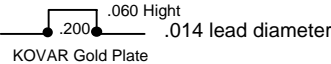
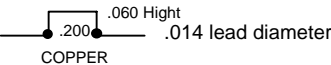
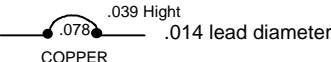
#	PACKAGE STYLE	PACKAGE INDUCTANCE
1	 Dip 14 Leads out top	15.7nH
2	 8-32 STUD	12nH
3	 10-32 STUD	11nH
4	 TO-5 (2 lead)	9.6nH
5	 TO-52	6.8nH
6	 Long Horn 14 Pin	6.4nH
7	 CD9mm	5.2nH
8	 .060 Hight .200 .014 lead diameter KOVAR Gold Plate	5.0nH
9	 .060 Hight .200 .014 lead diameter COPPER	3.6nH
10	 .039 Hight .078 .014 lead diameter COPPER	1.56nH

Table 1
Package Style Vs Package Inductance

Circuit Operation

Table 2 below provides the pin outs of connectors JP1 and J1. Figure 1 provides the component side silk of the PCO-7110 to facilitate locating the various components mentioned in this section

Connector JP1	
PIN 1	GND
PIN 2	15V @ 1mA +/-0.5mA
PIN 3	GND
PIN 4	GATE 5V into 50Ω
PIN 5	GND
PIN 6	NC
PIN 7	NC
PIN 8	NC
PIN 9	NC
PIN 10	HV IN, 0-195/495V @ I_{PS} (see eq. 1)

Connector J1	
PIN 1	GND
PIN 2	NC
PIN 3	CONDUCTOR

Table 2. PCO-7110 Connector Pin Out

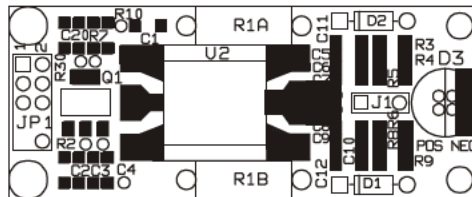


Figure 1. Component side silk

Referring to the above pin outs, there are three inputs: Trigger (GATE), Support Power (+15V) and DC High Voltage input (HV IN) on JP1. The **trigger** should be +5V into 50Ω, with a pulse width of 50ns to 100ns. The current requirement for the +15V power supply is very low, on the order of 1mA. Connector J1 is the output of the current monitor.

Connector JP1 is a DuPont/Berg #65611-172 two-row header on 0.1" centers. The header mates with a DuPont/Berg Mini-Latch Housing, part #65043-032 or equivalent, using DuPont/Berg mating receptacles #48236-000 or equivalent.

Connector J1 is a DuPont/Berg #65500-236 one-row header on 0.1" centers. The header mates with a DuPont/Berg Mini-Latch Housing, part #65039-034 or equivalent, using DuPont/Berg mating receptacles #48236-000 or equivalent.

A connector kit with the housings and receptacles for JP1 and J1 are available through DEI, as part #PCA-9210.

The **high voltage DC power supply** is either 195V, 400V or 495V maximum voltage, depending upon the PCO-7110 model (see the Specifications section for power specific maximum DC input voltages for each model. The maximum

average current that the high voltage supply must provide is determined by the pulse recurrence frequency required for the user's application.

Equation 1 has been derived in order to approximate ($\pm 20\%$) the current requirement (I_{PS}) of the high voltage power supply. It is a function of the total input capacitance (the Pulse Forming Network C_{PFN} , the FET capacitance C_{FET} , and the stray C_{STRAY}), the high voltage input (V_{IN}), and the frequency of each application (f).

$$1. I_{PS} = (C_{PFN} + C_{FET} + C_{STRAY}) * V_{IN} * f ,$$

where the various capacitances are given in Table 3.

PCO-7110 MODEL	40-4	50-15	100-7	120-15	90-30	45-65
C_{PFN}	1100pF	4000pF	1100pF	4080pF	10800pF	7000pF
C_{FET}	120pF	120pF	150pF	150pF	150pF	450pF
C_{STRAY}	200pF	430pF	550pF	600pF	100pF	100pF

Table 3. C_{PFN} values of the different PCO-7110 models

The output current of the PCO-7110 is adjusted by varying the applied voltage (V_{IN}). The output current depends upon the available charge of the C_{PFN} . This charge is directly proportional to the applied voltage. Therefore, varying the applied voltage will cause the output current to vary respectively. If the PCO-7110 driver is operated at less than maximum output current, the maximum DC input voltage specified may not be required.

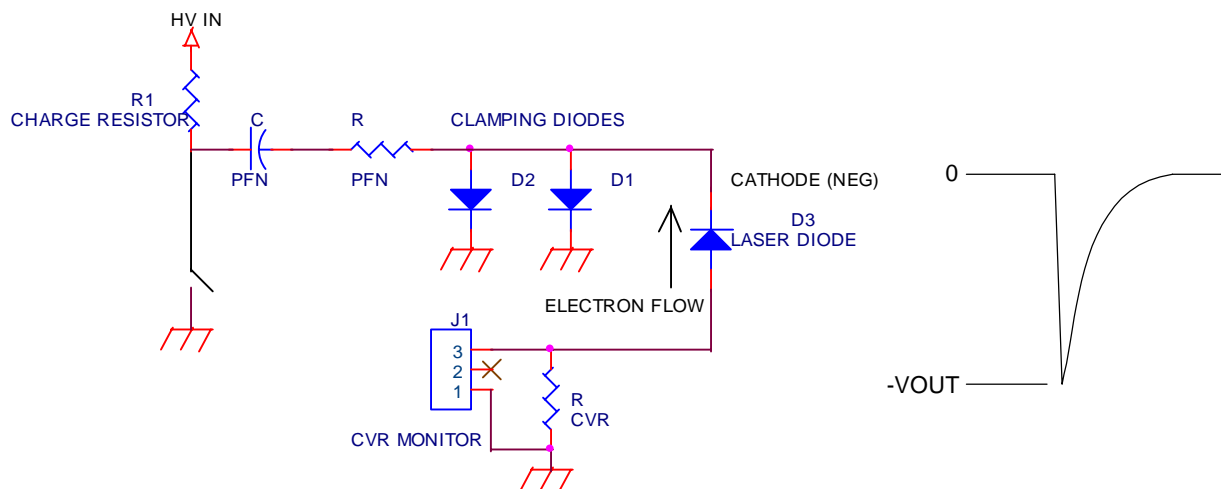


Figure 2. Equivalent Circuit Diagram and Output Waveform

Figure 2 is the equivalent circuit diagram of the PCO-7110. It shows the location of the C_{PFN} mentioned previously and the location of the laser diode in respect to the entire circuit. When monitoring the output waveform through J1, the waveform should approximate the one in Figure 2. For more details about

current monitoring and output waveforms refer to sections “Current Measurement” and “Typical Output Waveforms.”

D3 is the laser diode mounting location. It is marked on the silkscreen, and is separated in the middle with a line. The right-most two holes are negative (NEG) for the cathode while the other two are positive (POS) for the anode.

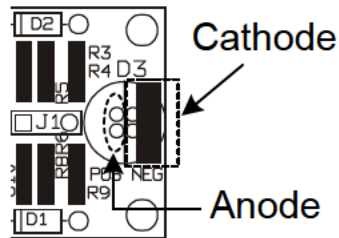


Figure 3. Cathode and Anode Pads on the PCB

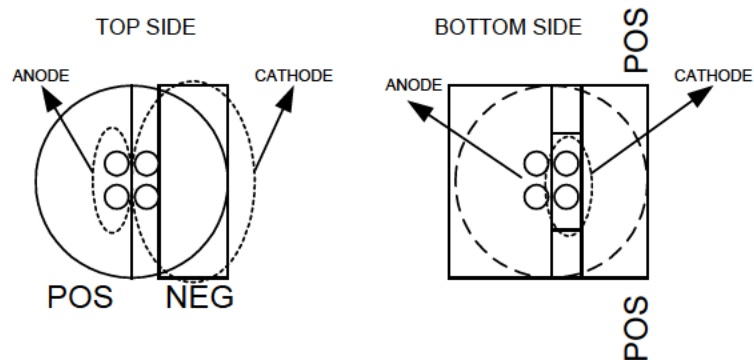


Figure 4. Detailed View of Cathode and Anode Pads on the PCB

Figures 3 and 4 show where the cathode and anode are located on the board. It is very important to mount the diode properly to avoid damaging it.

To facilitate different packages and user preferences, there are two strips of copper exposed; one on the top (component) side and one on the bottom (circuit) side of the PCB. The one on top is marked NEG and is for the cathode of the diode, while the one on the bottom is marked POS for the anode.

These pads are provided to facilitate mounting the diode perpendicular to the edge of the board (axial mount) as shown in Figure 5, rather than using the mounting holes. A stripline interconnect may also be soldered to these pads. The laser diode can then be soldered to the opposite end of the stripline, allowing remote mounting or installation of the laser diode.

These pads have no soldermask. If the diode case is connected to the anode of the diode, it is necessary to use an insulator when mounting the diode radially. This insulator should be for a TO-18 package, and will prevent the diode case from shorting to one of the pads. The driver is provided with kapton insulators. For higher average power applications, beryllium oxide (BeO) insulators are available upon request from DEI. The BeO insulators have lower thermal

impedance than the kapton insulators, and will therefore help to better dissipate heat in the laser diode package.

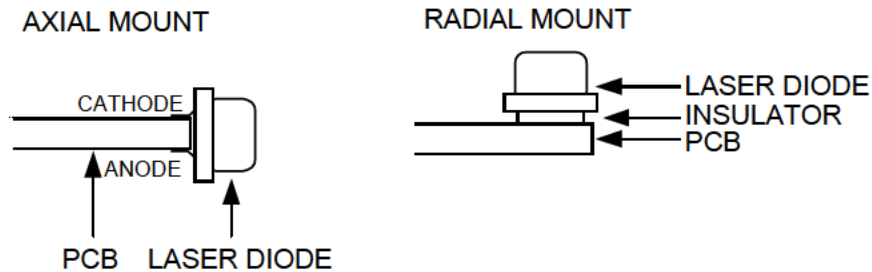


Figure 5. Axial and Radial Mounting Positions

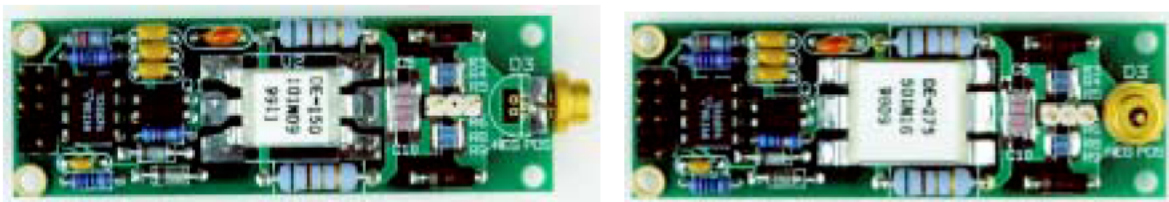


Figure 6: PCO-7110 Photos Showing Axially And Radially Mounted Laser Diodes

It is possible to mount the laser diode remotely using a strip line. It is imperative that this strip line be of low inductance. As mentioned in the "Design Considerations" section, inductance can greatly affect the circuit performance. Strip line material designed for use with the PCO-7110 is available from DEI (DEI stock #1820-0030).

Current Measurement

The current monitor signal provided on the PCO-7110 is available through connector J1. The output waveform will look very similar to that in Figure 2. Waveform photographs from an oscilloscope through the driver's internal monitor are included in the "Typical Output Waveforms" section.

The physical topology of the PCO-7110's current monitor resistors yields a Current Viewing Resistor (CVR) with a bandwidth of approximately 500MHz. Since the resistance value of the CVR is low as compared to a 50Ω scope input, the CVR can be directly coupled to an oscilloscope with 50Ω cable. Ground loops are eliminated by wrapping several (3-10) turns of the coaxial cable around and through a high μ ferrite torroid or pot core, forming a common mode choke. This technique provides an accurate ($\pm 3\%$), DC-500MHz current monitor, determined by

$$2. \quad I_{LD} = \frac{V_{CVR}}{R_{CVR}},$$

where I_{LD} is the output current, V_{CVR} is the value from the scope and R_{CVR} is the equivalent resistance of the 10 chip resistors that make up the driver's CVR ($\approx 0.1\Omega$). In this case, the corresponding current is 10A per 1V.

DEI provides an optional cable assembly (Part Number PCA-9140) with connectors to connect the current monitor output J1 to an oscilloscope input. This assembly is an RG-316 coax with a series termination of 50 Ohms at the CVR end, and a BNC connector on the other end. This in combination with the 50 Ohm terminator at the oscilloscope end will cause the above formula to become:

$$3. \quad I_{LD} = 2 * \frac{V_{CVR}}{R_{CVR}},$$

The series termination eliminates any current signal reflections. Using the DEI CVR monitor cable, because of the series 50 Ohm termination, the current monitor becomes $10A = 500mV$ from $10A = 1V$.

Specifications

The specifications in Table 4 below are for the six standard models. For OEM applications, the PCO-7110 can be configured to specific pulse width and output current levels to meet individual customer requirements - contact DEI for more information.

SPECIFICATIONS						
PCO-7110 MODEL	40-4	50-15	100-7	120-15	90-30	45-65
Pulse Output Current Range (Controlled by input high voltage amplitude)	4A to 40A	5A to 50A	5A to 100A*	5A to 120A*	5A to 95A*	4A to 45A
Maximum DC Input Voltage	+195V		+495V		+400V	+495V
Pulse Width (FWHM at maximum output current)	4ns ±1ns	15ns ±2ns	7ns ±1ns	15ns ±2ns	30ns ±3ns	65ns ±3ns
Rise Time (10% - 90%, Typical)	<2ns	2.5ns	2.5ns	2.5ns	<3ns	35ns
Maximum PRF (Pulse Recurrence Frequency), CW at maximum output current, controlled by input trigger	50KHZ	11KHz	5KHz**	2KHz	1KHz	1.5KHz
Maximum Duty Cycle (CW at maximum output current)	0.02%	0.0165%	0.0035%	0.003%	0.003%	0.01%
Jitter (1st Sigma)	<1ns					<2ns
Throughput Delay (Delay from input trigger to output pulse)	33ns Typical					55ns Typ.
Maximum Overshoot at maximum output current	5%					
Output Current Monitor	10A/V into 50 Ohms					
Trigger In	+5V/50Ω, 50-100ns pulse width					
Support Power	+15V at 2mA					
MECHANICAL						
Length	2.45 in. (62.2mm)					
Width	1.0 in. (25.4mm)					
Height	0.3 in. (7.5mm)					0.5 in. (12.7mm)
Weight (Approximate)	10 grams		12 grams			14 grams
Operating Temperature	-20°C to+85°C					
ALL SPECIFICATIONS MEASURED INTO A SHORTED OUTPUT AND MEASURED WITH THE INTERNAL CURRENT MONITOR						
SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE • LASER DIODE NOT INCLUDED						
* Maximum output current must be derated by 15% at operating temperatures above 60°C						
** Maximum current must be limited to 90A at frequencies above 2.5KHz.						

Table 4
PCO-7110 Specifications

Mechanical Specifications

Figure 7 contains the dimensions for the mounting holes of the standard PCO-7110, and Figure 8 is a detailed mechanical dimensional drawing. The mounting holes in the four corners are 0.125" through-holes, to clear a #4 screw.

These drawings facilitate the design of the mechanics of the supporting system.

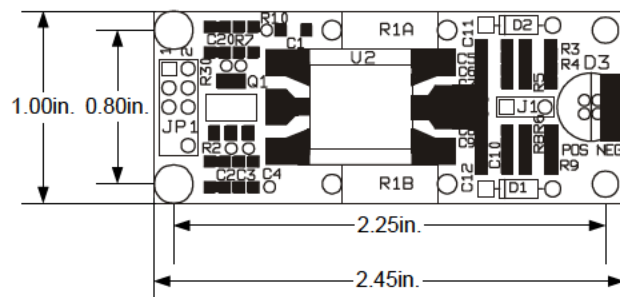


Figure 7: Mounting Hole Locations

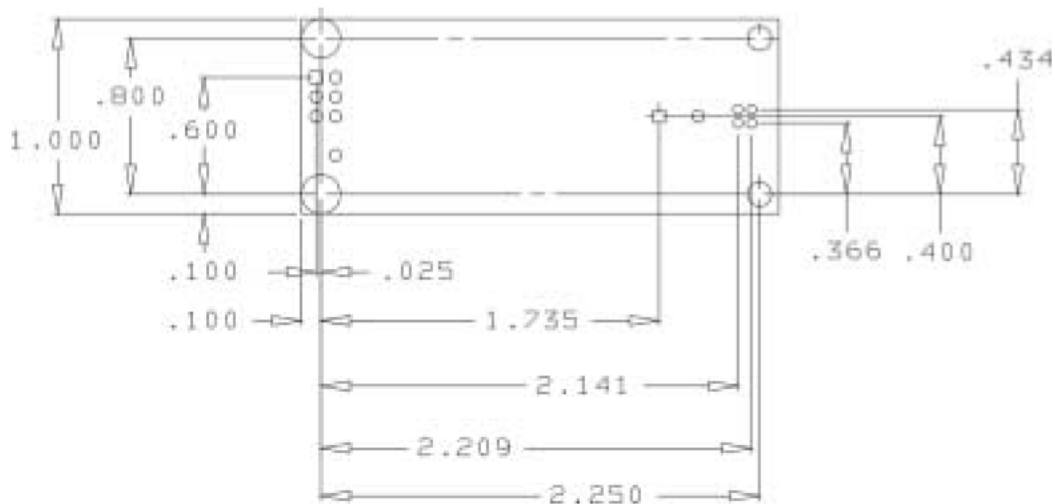
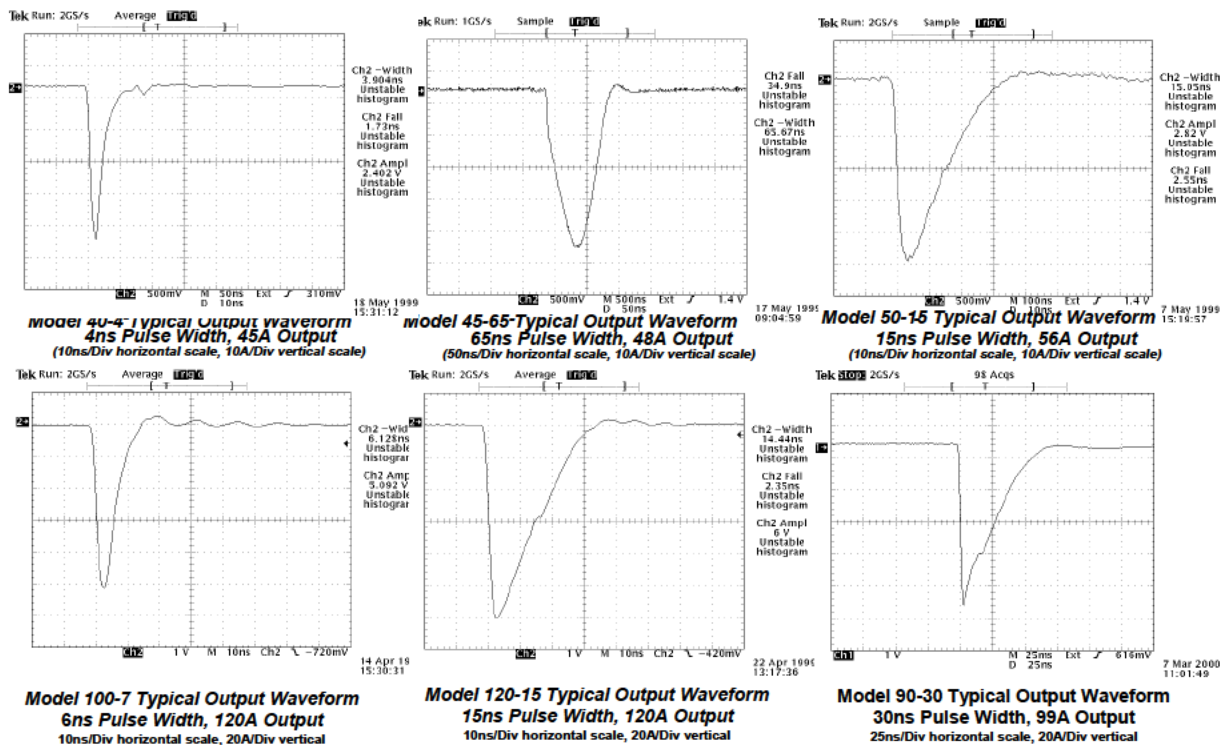


Figure 8: Detailed Mechanical Dimensions
(Mounting holes in corners are 0.125" through-holes)

Typical Output Waveforms

Below are typical output waveforms for the various PCO-7110 models. All waveforms are shown driving a short in place of the laser diode.



Warranty

There are no warranties, express or implied, including any implied warranty of fitness for a particular purpose nor any IMPLIED WARRANTY OF MERCHANTABILITY made by Directed Energy, Inc. (DEI) except as follows:

DEI warrants equipment manufactured by it to be free from defects in materials and/or workmanship under conditions of normal use for a period of one year from the date of shipment to the purchaser. DEI will repair or replace, at DEI's option, any product manufactured by it which is shown to be defective or fails to perform within specifications within one year from the date of shipment to the purchaser. OEM, modified and custom items of equipment are similarly warranted, for a period of ninety (90) days from date of shipment to the purchaser.

Equipment claimed to be defective must be returned, transportation prepaid, to DEI's factory in Fort Collins, Colorado within the warranty period. Returns must be preauthorized by contact with DEI's customer service department. Written documentation of such preauthorization shall be included with the returned item.

At DEI's discretion, DEI may elect to repair or replace the equipment claimed to be defective or refund the original purchase price, plus taxes and transportation charges incurred by the purchaser.

This Warranty shall not apply to any product that has been:

1. Repaired, worked on, or altered by persons unauthorized by DEI;
2. Subjected to misuse, neglect, or damage by others; or
3. Connected, installed, adjusted, or used in a manner not authorized in the instructions or specifications furnished by DEI.

This warranty is the purchaser's sole remedy for claimed defects in the equipment sold or manufactured by DEI. DEI's liability to the purchaser is limited to the repair or replacement of the claimed defective equipment or, at DEI's option, refund of the purchase price, taxes and transportation charges incurred by the purchaser. DEI will not be responsible for or liable to the purchaser for consequential losses or damages asserted to be attributable to a claimed defect in the equipment provided.

Changes made by DEI in the design or manufacture of similar equipment which are effected subsequent to the date of shipment of the warranted equipment to the purchaser are reflective of DEI's program of constant product development and improvement and shall not be construed as an acknowledgement of deficiency in the product shipped to purchaser. DEI will be under no obligation to make any changes to product previously shipped.